Atomic Parity Nonconservation in Stable Ytterbium Isotopes

D. Budker, S.J.Freedman, J.E. Stalnaker, and V. Yashchuk

The weak interaction, best known for its role in nuclear beta decay, also plays a minor role in the electronic structure of atoms. Although atomic structure is dominated by the electromagnetic interaction, it is possible to observe the weak interaction in atoms by studying the parity nonconserving (PNC) effects it brings about.

The $6s^2\ ^1S_0 \rightarrow 6s5d\ ^3D_1$ in atomic Yb is a promising systems for the study of PNC [1]. In the absence of parity nonconservation, the E1 transition amplitude is strictly forbidden by the parity selection rule, while the M1 amplitude is highly suppressed. The application of an external electric field mixes even and odd parity states, giving rise to a Stark-induced amplitude ($\mathrm{E1_{St}}$). The weak interaction also mixes even and odd parity states, giving rise to a parity nonconserving amplitude ($\mathrm{E1_{PNC}}$). In order to measure the very small $\mathrm{E1_{PNC}}$, one observes the interference between the much larger $\mathrm{E1_{St}}$ and $\mathrm{E1_{PNC}}$, as one excites this forbidden transition with intense laser light. The parity-violating effect in Yb is expected to be very large, due to the presence of two energetically-nearby states of opposite parity.

Precise measurements of PNC in single isotopes of Cs [2] and Tl [3], when combined with atomic structure calculations, have led to a determination of the weak mixing angle ($\sin^2\theta_\mathrm{W}$) as well as stringent limits on possible extensions to the Standard Model. Comparing PNC effects in several stable isotopes of Yb may allow us to extract information about the weak interaction independent of the atomic structure. The PNC effect for a given isotope also depends on the distribution of neutrons within the nucleus, a nuclear property not readily accessible by other means. In addition, comparison of PNC effects in the different hyperfine components of the two odd isotopes of Yb will allow for a determination of the nuclear anapole moment, a parity-violating electromagnetic moment of the nucleus.

In the past year we have continued work on a measurement of the highly forbidden M1 transition amplitude for the $6s^2\ ^1S_0 \rightarrow 6s5d\ ^3D_1$ transition through the method of Stark interference. This quantity is important in understanding possible systematic errors for future PNC results. This work is nearing completion and we are beginning to develop an experiment to measure the ac Stark-shifts for the transition.

[1] D. DeMille, Phys. Rev. Lett. 74, 4165(1995).
[2] C.S.Wood, et al., Science 271, 1759 (1997).
[3] P.A. Vetter, et al., Phys. Rev. Lett. 74, 2658 (1995).

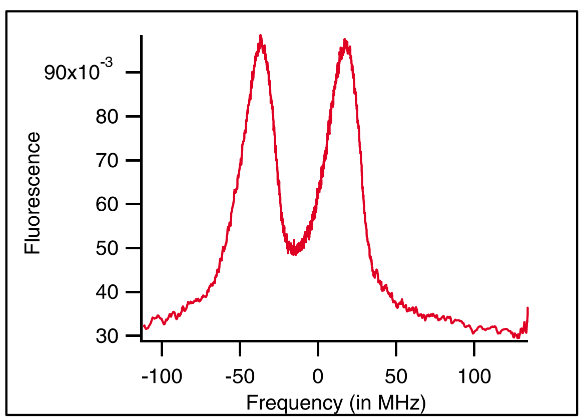

Figure 1: Laser-excitation spectrum of the 408 nm transition observed via fluorescence at 556 nm in the presence of a magnetic field for ^{174}Yb.